# **156.** *The Relation between Configuration and Conjugation in Diphenyl Derivatives. Part I. The Enantiomorphism and Ultra-violet Absorption Spectra of Some 2 : 2′-Bridged Compounds.*

By G. H. Beaven, D. Muriel Hall, Mary S. Lesslie, and E. E. Turner.

Various methods which have been used to investigate the configuration of the diphenyl skeleton, as it is present in a large variety of compounds, are reviewed. Compounds have been prepared in which the diphenyl skeleton is forced to assume a non-coplanar configuration by joining of the 2 : 2′-positions to produce a strainless multiplanar bridge. The ultra-violet absorption spectra of these compounds indicate that conjugation between the two benzene rings of the diphenyl skeleton still occurs. The introduction of methoxyl groups into the 6 : 6′-positions of the diphenyl part of these molecules, which can have little steric effect on the already twisted molecules, reduces the conjugation but results in considerable long-wave absorption. This is attributed to interaction between the methoxyl groups and the benzene rings to which they are attached, with consequent reduction in the double-bond character of the 1 : 1′-bond between the benzene rings. 2 : 7-Dihydro-4′ : 1″-dimethoxy-3 : 4-5 : 6-dibenzazepinium-1-*spiro*-1‴-piperidinium iodide has been resolved through the camphorsulphonates and is highly optically stable.

For a number of years after the acceptance of the collinear structure for diphenyls the problem of their configuration attracted little attention. When suitable *o*-substituents are present, the two benzene rings cannot become coplanar or rotate freely about the 1 : 1′-bond. This can be demonstrated unequivocally by optical resolution of typical compounds. In intermediate cases, the compounds can be optically activated but cannot be resolved. In compounds without 2-substituents and in compounds with small 2-substituents, coplanarity is not prohibited (these compounds cannot even be activated) and it was at one time considered that the stabilising effect of resonance between the two rings would operate to produce a structure in which at least the *preferred* configuration was a coplanar one. This view was supported by the results of *X*-ray crystal analysis of diphenyl (Dhar, *Indian J. Physics*, 1932, **7**, 43), which showed the molecule in the crystal to be coplanar and the 1 : 1′-bond distance to be 1·48 Å, and by calculation of the resonance energy of diphenyl from the heat of combustion, which gave a value of about 9 kcal./g.-mol. in excess of the sum of the resonance energies of the two benzene rings (Pauling and Sherman, *J. Chem. Physics*, 1933, **1**, 606, 679). The significance of the latter result is clearly diminished by the fact that diphenylmethane has been stated (Wheland, " The Theory of Resonance," 1944, p. 69) to have a comparable additional resonance energy.

During recent years, however, much rather conflicting evidence relating to diphenyl compounds has accumulated, some of which appears to indicate that even in diphenyl itself the preferred configuration of the isolated molecule is not coplanar. At the same time, a number of workers have suggested that partial loss of coplanarity is not necessarily associated with complete loss of resonance. Related to this concept is the growing body of evidence that substituents in the benzene ring may be forced out of the plane of the ring by other groups present (Klevens and Platt, *J. Amer. Chem. Soc.*, 1949, **71**, 1714; Bastiansen and Hassel, *Acta Chem. Scand.*, 1947, **1**, 489; Everard and Sutton, *J.*, 1949, 2312; 1951, 16; Newman and Hussey, *J. Amer. Chem. Soc.*, 1947, **69**, 3023; Newman and Wheatley, *J. Amer. Chem. Soc.*, 1948, **70**, 1913; Bell and Waring, *J.*, 1949, 2689; Badger and Pearce, *J.*, 1950, 3072).

The configuration of the diphenyl skeleton, as it is present in a large variety of compounds, has been investigated by the following methods : (1) The optical resolution (or asymmetric transformation) of compounds containing substituents in one or more of the 2 : 2′ : 6 : 6′-positions, together with a consideration of relative optical stabilities. (2) *X*-Ray crystal analysis. (3) Electron-diffraction in the vapour phase. (4) Dipole-moment measurements. (5) Ultra-violet absorption spectra.

With regard to method (1) it must be emphasised that in the case of compounds of high optical stability we are dealing with the impossibility of achieving certain configurations rather than with the problem of preferred configurations; activation energies for the configurational changes involved in racemisation are of the order of 20—30 kcal./g.-mol. It has proved satisfactory to represent such compounds by models in which covalent interatomic radii provide the dimensional data.

While methods (2) and (3) give unambiguous information about the configuration of the molecule in *particular physical states*, method (5) gives direct information only about conjugation between the two phenyl rings, although conclusions involving the relation between resonance and coplanarity of the phenyl rings have then been drawn.

In an attempt to determine the extent to which the ultra-violet absorption spectrum of a diphenyl compound is in fact a means of determining its configuration, we have investigated compounds in which structural features have been introduced into the molecule so that the configuration is fixed within comparatively small limits. Before describing this work we discuss the general applicability of the various methods and the results which have been obtained by their use. It may be noted that London (*J. Chem. Physics*, 1945, **13**, 396) computed the numerical values of the energy levels in diphenyl on the basis of a " flat-plane " structure for diphenyl, and regarded the good agreement between the theoretical electronic transitions and the observed ultra-violet absorption spectrum as favouring the coplanar model.

*X*-Ray crystallographic investigations give information as to the configuration of a molecule in the crystal. In addition to preferred molecular configurations we have to take into account intermolecular cohesive forces, and it is thus evident that the results of *X*-ray crystal analysis, while giving certain molecular dimensions with great accuracy, do not necessarily throw much light on the preferred configuration of the isolated molecule. Dhar's conclusions (*loc. cit.*) were based on determinations of the space group and the number of molecules per unit cell in the crystal of diphenyl, which show that the molecule has a centre of symmetry and therefore that the two benzene rings are here coplanar (see also Hengstenberg and Mark, *Z. Krist.*, 1929, **70**, 283; Clark and Pickett, *J. Amer. Chem. Soc.*, 1931, **53**, 167; Dhar, *loc. cit.*; *Proc. Nat. Inst. Sci. India*, 1949, **15**, 11). Similarly, Toussaint (*Acta Cryst.*, 1948, **1**, 43) concluded that 3 : 3′-dichlorobenzidine was planar (or nearly so) in the crystal, the chlorine atoms being in the "*trans*"-relationship. Yet in the crystal of 2 : 2′-dichlorobenzidine, Smare (*Acta Cryst.*, 1948, **1**, 150) found not only that the rings were at an angle of 72° to each other in a collinear arrangement having a 1 : 1′-bond of 1·53 Å, but further that the two chlorine atoms were "*cis*" rather than "*trans*," *i.e.*, were very much nearer together than one would have expected by comparison with the known preferred "*trans*"-configuration of ethylene dichloride in the vapour. Similarly, Fowweather and Hargreaves (*Acta Cryst.*, 1950, **3**, 81) concluded that in crystalline 2 : 2′-dimethylbenzidine dihydrochloride the respective dimensions were 71° and 1·52 Å, the two methyl groups having a "*cis*"-disposition. It is thus clear that some intramolecular repulsive forces may be overcome by the overriding effect of the cohesive forces in the forming crystal unit (cf. Bastiansen, *Acta Chem. Scand.*, 1949, **3**, 408).

Electron-diffraction investigation of vapours has the advantage of giving data concerning the *isolated* molecule and not a molecule which may have had to accommodate itself to the energetics of the crystalline state. Karle and Brockway (*J. Amer. Chem. Soc.*, 1944, **66**, 1974) favoured a non-coplanar diphenyl model with a 1 : 1′-bond of 1·54 ± 0·03 Å. Bastiansen (*loc. cit.*) added the refinement that in the collinear molecule the rings are inclined at an angle of 45° ± 10°. The same author deduced angles of 52° ± 10° and 54° ± 5° for 3 : 3′-dichlorobenzidine and 3 : 3′-dibromodiphenyl, respectively. For 2 : 2′-dichloro-, 2 : 2′-dibromo-, and 2 : 2′-di-iodo-diphenyl, Bastiansen (*Acta Chem. Scand.*, 1950, **4**, 926) found the angles to be 74°, 75°, and 79° respectively (1 : 1′-bond, 1·50 ± 0·03 Å), the halogen atoms being, surprisingly, "*cis*" rather than "*trans*." All these figures relate to average configurations. Those for diphenyl itself fit in reasonably well with what one might expect in comparing, by means of models, the now generally accepted preferred configuration in ethane with that of diphenyl, assuming that the 1 : 1′-bond is essentially single. In both molecules repulsive forces between hydrogen atoms are from this point of view looked on as the controlling factor (compare Pauling, "The Nature of the Chemical Bond," 1942, p. 219) and in both cases one should speak not of "restricted" rotation [a term to which Mills and Elliott (*J.*, 1928, 1291) gave a precise meaning in connection with compounds having observable optical activity] but of something more indefinite, *e.g.* "hindered" rotation.

Dipole-moment measurements of diphenyl compounds can provide two distinct types of information. With 2 : 2′-disubstituted diphenyls it is possible to determine whether or not the molecule is predominantly planar (since, if it is, the dipole moment will either be zero for the "*trans*"-planar configuration or have a readily calculable value for the "*cis*"-planar one). In fact, such measurements indicate non-coplanar structures (Bretscher, *Helv. Physica Acta*, 1929, **2**, 257; Weissberger and Sängewald, *Z. physikal. Chem.*, 1933, *B*, **20**, 145; Hampson and Weissberger, *J. Amer. Chem. Soc.*, 1936, **58**, 2111; Le Fèvre and Vine, *J.*, 1938, 967; Lumbroso, *Bull. Soc. chim.*, 1949, **16**, D 387). On the other hand, dipole-moment measurements of 4 : 4′-disubstituted diphenyls (where the groups in the 4- and the 4′-position are different) can contribute information about resonance interaction between the substituents in the two rings and hence between the two rings themselves. The dipole moment of 4-amino-4′-nitrophenyl (Le Fèvre and Le Fèvre, *J.*, 1936, 1130) shows that such interaction occurs.

Pickett, Walter, and France (*J. Amer. Chem. Soc.*, 1936, **58**, 2296) studied the ultra-violet absorption spectra of diphenyl compounds in which the four *ortho*-positions were (*a*) substituted and (*b*) unsubstituted. In the former case the spectra were essentially those of the two corresponding benzene compounds, but in the latter case the spectra were very different and showed, as with diphenyl itself, a high-intensity band at *ca.* 2500 Å with a maximal molecular extinction coefficient of *ca.* 20 000 which arises as a result of resonance between the two aromatic nuclei, the 1 : 1′-bond acquiring some double-bond character. Such conjugation of the two phenyl groups operates by overlapping of the $\pi$ orbitals of the 1 : 1′-carbon atoms, and has generally been assumed to require the coplanarity of the two phenyl groups (see Wheland, *op. cit.*, p. 92, etc., for review and references). Further spectroscopic evidence of conjugation between the two rings in non-*ortho*-substituted diphenyls has been given by Gillam and Hey (*J.*, 1939, 1170), Pestemer and Mayer-Pitsch (*Monatsh.*, 1937, **70**, 104), Calvin (*J. Org. Chem.*, 1939, **4**, 256), O'Shaughnessy and Rodebush (*J. Amer. Chem. Soc.*, 1940, **62**, 2906), Williamson and Rodebush (*ibid.*, 1941, **63**, 3018), and others.

However, diphenyls in which only two of the four *ortho*-positions are substituted, *e.g.*, 2 : 2′-dimethyldiphenyl, also fail to exhibit the characteristic intense diphenyl band, indicating the absence of conjugation between the two phenyl rings (O'Shaughnessy and Rodebush, *loc. cit.*; Williamson and Rodebush, *loc. cit.*). The conclusion has been drawn that this phenomenon is associated with inability to assume a coplanar structure owing to interference between the 2-substituents and the 2′- and 6′-hydrogen atoms, especially as 2 : 2′-dihydroxydiphenyl (where the interfering effect of the hydroxyl groups is comparatively small) has a spectrum showing the characteristics both of a conjugated diphenyl and of phenol (Williamson and Rodebush, *loc. cit.*), and is presumably an intermediate case. On the other hand, such compounds do not exhibit optical activity, and presumably their passage through coplanarity does not involve a significant energy barrier.

Friedel, Orchin, and Reggel (*J. Amer. Chem. Soc.*, 1948, **70**, 199) report that 2-methyl-, 2-methoxy-, and 2-hydroxy-diphenyl all show hindered rotation effects in their ultraviolet absorption spectra. Reduction in conjugation as a result of steric interaction between the 2-substituents and the 2′- and 6′-hydrogen atoms was inferred by these authors from the reduced intensities and slight short-wave shifts of the *ca.* 2500-Å conjugation bands. The bands at *ca.* 2840 Å in 2-hydroxy- and 2-methoxy-diphenyl were considered to be "phenoxy"-bands, originating in the unconjugated phenyl groups containing the substituents. The high intensities of these bands ($\varepsilon_{max.}$ *ca.* 5000) must be due in part to overlapping by the long-wave sides of the more intense conjugation bands; in simple phenols and alkoxybenzenes their intensities are *ca.* 2000 (see Morton, "Practical Aspects of Absorption Spectrophotometry," Royal Inst. of Chemistry, 1938).

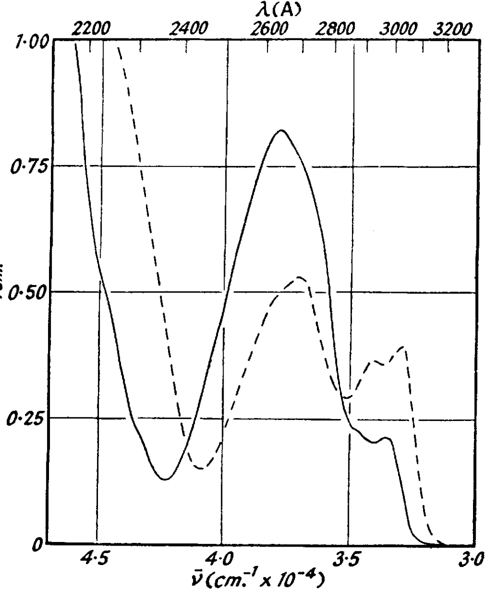
The criteria used by Friedel *et al.* are essentially those which have generally been applied to the interpretation of the spectra of diphenyls with hindered rotation, although not all authors have specifically assigned any long-wave absorption features to unconjugated phenyl groups acting as partial chromophores. In some compounds, *e.g.*, 2-methyldiphenyl (Friedel *et al.*, *loc. cit.*), the only indication of any absorption contribution of this type is a faint inflection on the long-wave side of the conjugation band, and such small effects have sometimes been ignored, attention being concentrated on alterations in the conjugation band only.

Rodebush and Feldman (*J. Amer. Chem. Soc.*, 1946, **68**, 896) conclude that the ultraviolet absorption spectrum of diphenyl is not incompatible with a non-coplanar model but add : "All that can be stated with certainty from the spectrographic studies is that in the unsubstituted diphenyls the configuration is near enough to coplanarity to allow a resonance energy amounting to several large calories." This conclusion is an indirect one in the sense that it is based on the assumption that the appearance of the high intensity band at *ca.* 2500 Å is dependent on conjugation between the two phenyl groups, for which their approximate coplanarity is regarded as a necessary condition.

In the coplanar configuration the *resonance* energy of the parent diphenyl system is presumably maximal, but with the introduction of a 2-substituent two new factors are introduced : (1) the space-requirements of the 2-group in relation to the 2′- and 6′-positions; (2) the electronic interaction of the 2-substituent with the ring to which it is attached. The second factor can clearly either support or oppose the fundamental diphenyl resonance, while the first effect must always be in opposition to it. Most workers have concentrated on the first factor, and it would appear that in many cases they have attained good correlation of experiment and inference. But since 2 : 2′-dimethyldiphenyl has very little diphenyl absorption (O'Shaughnessy and Rodebush, *loc. cit.*) and yet introduction of 4 : 4′-dinitro-groups restores almost the full diphenyl conjugation band (Sherwood and Calvin, *J. Amer. Chem. Soc.*, 1942, **64**, 1350; compare Pickett, Groth, Duckworth, and Cuncliffe, *ibid*, 1950, **72**, 44), it would appear that the interaction of a substituent with the aromatic ring to which it is attached can in some cases be more important in determining the type of absorption than the sterically-sensitive interaction of the two aromatic rings. In our present incomplete state of knowledge, caution is necessary in interpreting the effect of substitution on the "configuration" of a diphenyl as indicated by its ultra-violet absorption spectrum.

In this connection attention must be drawn to a frequently quoted (cf. Bastiansen, 1949, *loc. cit.*; Clar, *Spectrochim. Acta*, 1950, **4**, 116; Hodgkin and Pitt, *Ann. Reports*, 1950, **47**, 459) note by Merkel and Wiegand (*Z. Naturforsch.*, 1948, **3**, *b*, 93), who suggested that compounds containing two coplanar linked (or linked and bridged) benzene rings give steep absorption bands with well-resolved fine-structure, and that non-coplanarity is associated with broad absorption bands showing no fine-structure. On the basis of these criteria the experimental data for diphenyl indicated it to be planar in the crystalline state, and non-coplanar not only in the vapour state but also in solution. Merkel and Wiegand's conclusions are, however, not free from ambiguity. It has frequently been shown (for review, see Jones, *J. Amer. Chem. Soc.*, 1945, **67**, 2131) that the introduction of methylene bridges into compounds containing linked aromatic rings, resulting in the formation of strained rigid structures, may be accompanied by a marked enhancement of fine-structure, *e.g.*, as in fluorene. In fused polycyclic aromatic compounds symmetry restrictions result in some of the low-intensity electronic transitions being forbidden, unless accompanied by simultaneous vibrational transitions. Conversely, the broad high-intensity conjugation bands of compounds containing linked benzene rings are permitted, and are active in absorption without the necessity for simultaneous vibrational transitions. Furthermore, fine-structure in the crystalline state must be to some extent influenced by intermolecular lattice forces, and in solution by interaction with solvent molecules (as indicated by low-temperature studies in rigid solvents). For these reasons it seems that Merkel and Wiegand's criteria are more likely to distinguish between compounds which approximate to the polycyclic aromatic type, being both rigid and coplanar, and compounds containing linked benzene rings in which coplanarity may be possible (and indeed facilitated by resonance stabilisation) but may be opposed by steric factors and bond-angle restrictions in strainless bridges. Thus in 2 : 2′ : 6 : 6′-tetrasubstituted diphenyls fine-structure is associated with the low-intensity absorption contributions of the unconjugated partial benzenoid chromophores, and is here an indication not of coplanarity but of its absence.

FIG. 1. —— 9 : 10-*Dihydrophenanthrene*, 4·59 × $10^{-5}$ *mole/l.* - - - 9 : 10-*Dihydro*-4 : 5-*dimethoxyphenanthrene* (I), 3·86 × $10^{-5}$ *mole/l.* *Solvent, hexane.*



By suitably joining the 2 : 2′-positions in diphenyl, molecules can be produced which combine the basic collinear diphenyl structure with a strainless multiplanar bridge and should therefore exist in optically stable enantiomeric forms, irrespective of further substitution in the 6 : 6′-positions. The simplest 2 : 2′-bridged diphenyl, fluorene, does not satisfy this requirement and is best regarded as a strained planar structure of the type noted above; it is thus unsuitable for our present purpose.

Bridging the 2 : 2′-positions in diphenyl by two methylene groups apparently involves no strain, the diphenyl skeleton remaining collinear and the carbon atoms of the two methylene groups having their normal tetrahedral angles. A model suggests that the angle between the two collinear phenyl rings in 9 : 10-dihydrophenanthrene is about 20° (compare Jones, *J. Amer. Chem. Soc.*, 1941, **63**, 1658). The ultra-violet absorption spectrum has been studied by several authors (Askew, *J.*, 1935, 509; Craig, Jacobs, and Lavin, *J. Biol. Chem.*, 1941, **139**, 277; Jones, *loc. cit.*; Braude, *J.*, 1949, 1902).

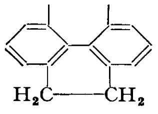
Our measurements are in agreement with the results of the above workers. The compound shows (Fig. 1 and table) a typical high-intensity diphenyl band at $\lambda_{\text{max.}}$ 2635 Å, $\varepsilon_{\text{max.}}$ 18 000, and a broad but definitely resolved low-intensity band at longer wave-length, $\lambda_{\text{max.}}$ 2995 Å, $\varepsilon_{\text{max.}}$ 4750. Jones (*loc. cit.*) ascribed this band to the bathochromic effect of the 9 : 10-methylene groups acting simply as alkyl substituents. This explanation was criticised by Braude (*loc. cit.*), who suggested that the relatively high intensity of the long-wave band was an indication of interaction between the two phenyl groups through the $\cdot CH_2\cdot CH_2\cdot$ linkage, so that this band had its origin in the same way as the long-wave band in fluorene ($\lambda_{\text{max.}}$ 3000 Å, $\varepsilon_{\text{max.}}$ 10 000), its lower intensity being attributed to a lower degree of interaction through two methylene groups. It seems more satisfactory to regard 9 : 10-dihydrophenanthrene as a diphenyl which is sufficiently non-coplanar for the conjugation through the 1 : 1'-bond * to be reduced, leading to the appearance of absorption contributions from the separate unconjugated phenyl chromophores.

*Ultra-violet absorption spectra of* 2 : 2'-*bridged diphenyls.*

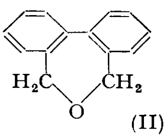
| Compound | Solvent | Short-wave band | | | | Long-wave band | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $\lambda_{\text{min.}}$ | $\varepsilon_{\text{min.}}$ | $\lambda_{\text{max.}}$ | $\varepsilon_{\text{max.}}$ | $\lambda_{\text{min.}}$ | $\varepsilon_{\text{min.}}$ | $\lambda_{\text{max.}}$ | $\varepsilon_{\text{max.}}$ |
| Diphenyl | Hexane | 2215 | 4 000 | 2475 | 19 000 | — | — | — | — |
| | Ethanol | 2220 | 5 100 | 2490 | 18 000 | — | — | — | — |
| 9 : 10-Dihydrophenanthrene | Hexane | 2365 | 2 850 | 2635 | 18 000 | — | — | 2995 | 4 750 |
| | | | | | | | | (2895) | 4 950 |
| | Ethanol | 2370 | 2 650 | 2640 | 17 000 | — | — | 2995 | 4 450 |
| | | | | | | | | (2895) | 4 200 |
| (I) 9 : 10-Dihydro-4 : 5-dimethoxyphenanthrene | Hexane | 2450 | 3 800 | 2710 | 13 500 | 2850 | 7550 | 3045 | 10 500 |
| | | | | (2630) | 12 500 | | | 2930 | 9 400 |
| | Ethanol | 2450 | 3 800 | 2720 | 13 500 | 2860 | 7350 | 3045 | 9 300 |
| | | | | (2630) | 12 500 | | | 2930 | 8 650 |
| (II) 2 : 7-Dihydro-3 : 4-5 : 6-dibenzoxepin | Hexane | 2260 | 5 700 | 2500 | 16 500 | — | — | — | — |
| (III) 2 : 7-Dihydro-4' : 1''-dimethoxy-3 : 4-5 : 6-dibenzoxepin | Hexane | — | — | 2530 | 8 650 | 2630 | 2450 | 2935 | 9 950 |
| | | | | (2460) | 9 300 | | | 2835 | 9 400 |
| (V) 2 : 7-Dihydro-3 : 4-5 : 6-dibenzazepinium-1-*spiro*-1'''-piperidinium bromide | Water | 2240 | 4 500 | 2480 | 15 000 | — | — | (2815) | 2 250 |
| | | | | | | | | (2720) | 4 750 |
| (VIII) 2 : 7-Dihydro-4' : 1''-dimethoxy-3 : 4-5 : 6-dibenzazepinium-1-*spiro*-1'''-piperidinium bromide | Water | 2335 | 11 000 | 2375 | 11 500 | 2610 | 1450 | 2975 | 10 500 |

Wave-length values in parentheses denote inflections, as located by moving-plate spectrograms.

In 9 : 10-dihydro-4 : 5-dimethoxyphenanthrene (I) (Hall and Turner, *J.*, 1951, 3072) the conjugation band ($\lambda_{\text{max.}}$ 2710 Å) is of lower intensity than in 9 : 10-dihydrophenanthrene, but the long-wave band ($\lambda_{\text{max.}}$ 3045 Å) has increased in intensity and shows some fine-structure ($\lambda_{\text{max.}}$ 2930, 3045 Å) (Fig. 1).



(I)



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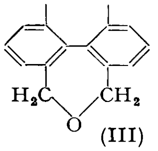

(III)

Bridging of the 2 : 2'-positions of diphenyl by a 7-membered ring is particularly easy, corresponding to the formation of a strainless ring (compare Kenner and his co-workers, *J.*, 1911, **99**, 2101, and later papers). Thus 2 : 7-dihydro-3 : 4-5 : 6-dibenzoxepin (II) is

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* Whenever the term 1 : 1'-bond is used the numbering refers to the diphenyl skeleton present in the molecule irrespective of the numbering of the molecule as a whole.

readily formed by the internal etherification of 2 : 2′-bishydroxymethyldiphenyl in presence of warm dilute mineral acid. The presence of methoxyl groups in the 6 : 6′-positions in the bishydroxymethyldiphenyl does not appear to diminish the ease of internal etherification and 2 : 7-dihydro-4′ : 1″-dimethoxy-3 : 4-5 : 6-dibenzoxepin (III) (Hall and Turner, *loc. cit.*) must also, in the light of this evidence, have a practically strainless structure. In this and the parent oxepin, the angle between the collinear phenyl rings is, according to the model, about 50°.

The ultra-violet absorption spectrum (Fig. 2) of the simple oxepin, however, shows no trace of any long-wave selective absorption, but only a high-intensity band at $\lambda_{max.}$ 2500 Å, $\varepsilon_{max.}$ 16 500 (hexane). Compared with diphenyl, the position of this band shows a slight long-wave shift (presumably owing to the bathochromic effects of the methylene groups) and a slight reduction in intensity of the maximum. The presence and intensity of this band, together with the absence of any long-wave absorption features (confirmed by moving-plate spectrograms), would suggest that in the oxepin the phenyl groups are no less conjugated and hence no less coplanar than in diphenyl. Since, however, the oxepin cannot be coplanar, it follows that the diphenyl-type spectrum does not provide sure evidence for a coplanar configuration.

FIG. 2.

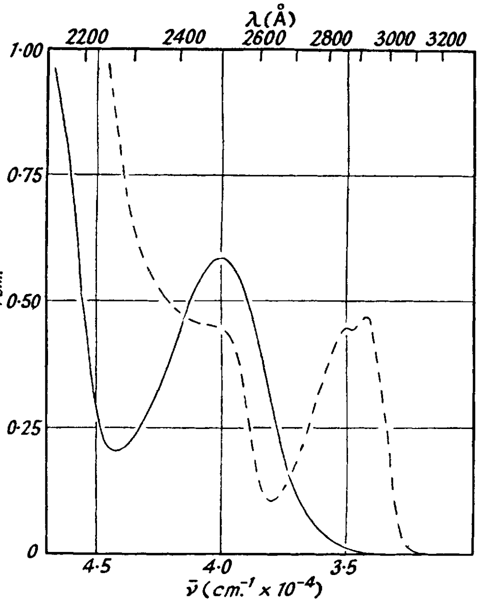


FIG. 3.

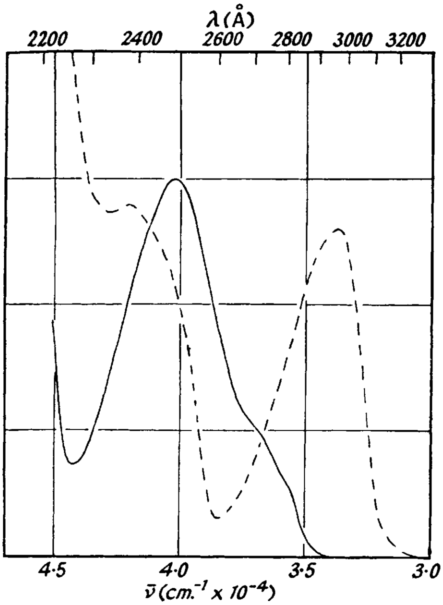
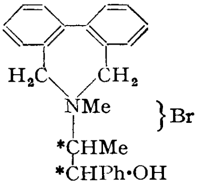


FIG. 2. —— 2 : 7-*Dihydro*-3 : 4-5 : 6-*dibenzoxepin* (II), 3·52 × $10^{-5}$ *mole/l.* - - - 2 : 7-*Dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzoxepin* (III), 4·74 × $10^{-5}$ *mole/l. Solvent, hexane.*

FIG. 3. —— 2 : 7-*Dihydro*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium bromide* (V), 5·05 × $10^{-5}$ *mole/l.* - - - 2 : 7-*Dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium bromide* (VIII), 6·67 × $10^{-5}$ *mole/l. Solvent, water.*

With the 4′ : 1″-dimethoxy-compound (III) the ultra-violet absorption spectrum (Fig. 2) shows a perceptible short-wave shift and marked reduction in intensity of the conjugation band, together with the appearance of a strong long-wave band at 2935 Å. Both these changes are indicative of marked reduction in conjugation between the phenyl rings, and on the basis of previous work would be interpreted as indicating a large departure from the presumed coplanarity of the parent oxepin. Such an interpretation is clearly untenable in view of the multiplanar configuration of the parent oxepin, and some other explanation of the differences in the spectra of the two oxepins, and also of the two dihydrophenanthrenes, must be sought.

Attention was now directed to the preparation of 7-ring-bridged diphenyls containing a group which would permit of attempted optical resolution. 2 : 2′-Bisbromomethyldiphenyl reacts vigorously with strong secondary bases to give dibenzazepinium compounds. Thus (+)-ephedrine gives 2 : 7-dihydro-1-(2-hydroxy-1-methyl-2-phenylethyl)-1-methyl-3 : 4-5 : 6-dibenzazepinium bromide (IV) which, if the cyclic system is dissymmetric, should be a mixture of diastereoisomerides. We were, however, unable to separate either the bromide or the corresponding iodide into two substances. Interaction of the dibromo-compound and piperidine gave 2 : 7-dihydro-3 : 4-5 : 6-dibenzazepinium-1-*spiro*-1‴-piperidinium bromide (V). Crystallisation of the corresponding (+)-camphorsulphonate and the (+)-α-bromocamphor-π-sulphonate from solvents did not lead to any conclusive separation into two fractions of different rotatory power. The crystallisations had none of the characteristics of second-order asymmetric transformation such as would have been possible and indeed expected had the configuration been unstable. In our view, the optical rotation of a compact rigid structure such as the one under investigation might well be expected to be of a low order, so that the *difference* in rotation between the two expected diastereoisomerides could easily be too small for the purposes of practical resolution.



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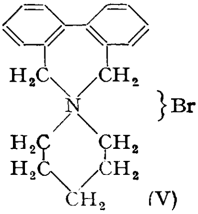

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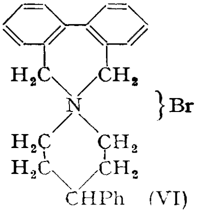
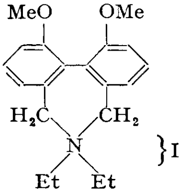


(VI)

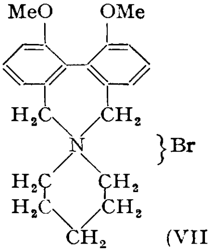
In the hope of augmenting the rotatory power, we prepared 2 : 7-dihydro-4‴-phenyl-3 : 4-5 : 6-dibenzazepinium-1-*spiro*-1‴-piperidinium bromide (VI) in which the CHPh group can only take part in the general dissymmetry because the diphenyl skeleton is twisted.

Crystallisation of the corresponding (+)-camphorsulphonate from various solvents led to no definite resolution, but on one occasion the (+)-α-bromocamphor-π-sulphonate when crystallised from water, gave two apparently different crops, one with $2H_2O$ and the other with $\frac{1}{2}H_2O$ of crystallisation. These salts, however, had practically indistinguishable rotations, and resolution clearly cannot be claimed.

As an alternative approach we condensed 2 : 2′-bisbromomethyl-6 : 6′-dimethoxydiphenyl with diethylamine and with piperidine, in the hope that introduction of the methoxyl groups, which could not have a determinative effect on the order of stability of the configuration of the quaternary salts as compared with that of the methoxyl-free compound, would enhance the rotation and thus make the resolution process practicable. It was noted that these quaternary salts were formed as readily as were those from the methoxyl-free dibromide, and it is evident that the formation of the 7-membered ring is less sterically affected than that of the 6-membered ring in the 9 : 10-dihydrophenanthrene series (Hall and Turner, *loc. cit.*).



(VII)



(VIII)

The quaternary (+)-camphorsulphonate derived from 1 : 1-diethyl-2 : 7-dihydro-4′ : 1″-dimethoxy-3 : 4-5 : 6-dibenzazepinium iodide (VII) proved difficult to manage as regards practical crystallisation, and the (+)-α-bromocamphor-π-sulphonate was obtained as, and remained, a gum. Of the quaternary salts derived from 2 : 7-dihydro-4′ : 1″-dimethoxy-3 : 4-5 : 6-dibenzazepinium-1-*spiro*-1‴-piperidinium bromide (VIII), the (+)-α-bromocamphor-π-sulphonate, the hydrogen (+)-tartrate, and the (—)-menthyl phthalate could not be obtained crystalline. On the other hand, the (+)-camphorsulphonate crystallised well either from acetone or from acetonitrile. With the former solvent no evidence of resolution was obtained, but by an elaborate series of fractional crystallisations from acetonitrile a slight initial separation was ultimately developed and two salts having $[\alpha]^{21}_{5461}$ +19·0° and $[\alpha]^{20}_{5461}$ +24·7° (in ethanol) were isolated. To prepare the (—)-camphorsulphonate we used silver (—)-camphorsulphonate containing about 10% of (±)-salt and as a result the two extreme rotations found were $[\alpha]^{18}_{5461}$ —14·5° (*i.e.*, containing racemate) and $[\alpha]^{19}_{5461}$ —23·3°. Neither in the (+)- nor in the (—)-series was it possible to obtain the more soluble diastereoisomeride pure, but by treating the less soluble forms with potassium iodide we obtained iodides with $[\alpha]^{22}_{5461}$ —3·8° ± 0·2° [from the (+)-camphorsulphonate] and $[\alpha]^{22}_{5461}$ +4·0° ± 0·4° [from the (—)-camphorsulphonate] in acetonitrile. The completion of the purification of the active iodides was complicated by the appearance of dimorphic crystals (see Experimental).

The (+)-camphorsulphonate was not measurably racemised after being heated at 100° for two hours in ethanolic solution. The (+)-iodide was recovered with unchanged rotation after its aqueous solution had been boiled for 7 hours. When a solution of the (+)-iodide in a mixture of anisole and *cyclo*hexanol was boiled for 5 hours, the rotation of the recovered salt was unchanged. Partial racemisation of the (—)-iodide occurred when a *cyclo*hexanol solution was boiled (160°) for 8 hours, and complete racemisation when the process was continued for a further 8 hours. These facts are evidence of very considerable optical stability. The contrasting optical instability of 3 : 3′-diamino-2 : 2′ : 6 : 6′-tetramethoxydiphenyl (the dicamphorsulphonate of which mutarotates rapidly in solution at — 17°; Van Arendonk, Cupery, and Adams, *J. Amer. Chem. Soc.*, 1933, **55**, 4225) greatly strengthens our view that the methoxyl groups in (VIII) are only of secondary importance in affecting configurational stability.

The absorption spectrum (Fig. 3) of the 2 : 7-dihydro-3 : 4-5 : 6-dibenzazepinium-1-*spiro*-1‴-piperidinium cation (V) (examined as the bromide in water) shows a high-intensity band, $\varepsilon_{\text{max.}}$ 15 000, at a position $\lambda_{\text{max.}}$ 2480 Å, only slightly displaced to a shorter wave-length than that in diphenyl ($\lambda_{\text{max.}}$ 2490 Å, $\varepsilon_{\text{max.}}$ 18 000 in ethanol). This small shift and slight reduction in intensity suggest only a small departure from conjugation of the phenyl rings, of the same order as is indicated by the absorption spectrum for some 2-monosubstituted diphenyls. The sole evidence in the spectrum of (V) of any departure from diphenyl type is the existence of two long-wave inflections, $\lambda\lambda_{\text{infl.}}$ 2720, 2815 Å, which are just visible in the spectrogram as alterations in the contour of the long-wave foot of the high-intensity band; they can be located with precision by the moving-plate method. These inflections are of fairly low intensity, which is consistent with the high intensity of the short-wave band, on which in fact they are largely superimposed.

In (VIII) (Fig. 3) there is a large short-wave shift and appreciable reduction in intensity of the short-wave band, $\lambda_{\text{max.}}$ 2375 Å, $\varepsilon_{\text{max.}}$ 11 500 (in water, examined as the bromide), suggesting a considerably reduced interaction between the phenyl groups, as in the dimethoxyoxepin. Furthermore, as in the case of the dimethoxyoxepin (III), there is a well-resolved long-wave band of comparable intensity, $\lambda_{\text{max.}}$ 2975 Å, $\varepsilon_{\text{max.}}$ 10 500, which is completely separated from the 2375 Å band by a deep minimum at 2610 Å. In this compound, therefore, the short-wave band does not contribute significantly to the observed intensity of the long-wave absorption feature. There is a further striking departure from the normal diphenyl spectrum on the *short-wave* side of the 2375 Å band. Instead of the characteristic minimum which occurs at $\lambda_{\text{min.}}$ 2220 Å, $\varepsilon_{\text{min.}}$ 5100 for diphenyl itself, and at $\lambda_{\text{min.}}$ 2240 Å, $\varepsilon_{\text{min.}}$ 4500 in (V), in the dimethoxy-derivative (VIII) this minimum is almost abolished, relatively to the adjacent maximum, by the long-wave side of a very high-intensity band at still shorter wave-length with $\lambda_{\text{max.}}$ *ca.* 2100—2200 Å, $\varepsilon_{\text{max.}}$ *ca.* 40 000 or higher. It seems reasonable to identify this band as the high-intensity short-wave band of the benzenoid partial chromophore, but shifted to a longer wave-length. Its high intensity must be due in part to overlapping by the short-wave side of the displaced conjugation band at 2375 Å, but the relatively high intensity of the band at 2975 Å, which we shall regard as the long-wave band of the same chromophore, of the order of $\varepsilon_{\text{max.}}$ *ca.* 5000 per phenyl group, suggests that there has been considerable enhancement of the intensities of both; the large red shift of the long-wave band is a further indication that the benzenoid partial chromophores are under the influence of strong bathochromic and hyperchromic factors.

It is evident that the present results are not explicable solely on the basis of the hitherto accepted relationship between coplanarity and conjugation of the phenyl groups in substituted diphenyls. Thus the oxepins (II, III) and azepinium salts (V, VIII) would be expected to show no conjugation bands, as the two benzene rings in these compounds, although collinear, are not coplanar. Furthermore, the introduction of *oo'*-methoxyl groups, as in (III) and (VIII), should have no steric consequences if the phenyl groups are already incapable of conjugation in the parent compounds. The observed absorption spectra are in complete disagreement with both these expectations, but may be accounted for by the introduction of two hypotheses which have not been sufficiently considered in the interpretation of the absorption spectra of substituted diphenyls, though the necessity for them may also be seen from a scrutiny of some of the previous work in this field. These are (*a*) that coplanarity of the two benzene rings is not essential for the appearance of the conjugation band in *oo'*-substituted diphenyls, and large departures from coplanarity may be accommodated without complete loss of conjugation; and (*b*) that in diphenyls which show a conjugation band the introduction of additional groups may reduce the intensity of the band, even when their presence is without steric effect on the configuration. The justification for introducing the first hypothesis admittedly rests on the correct identification of the *ca.* 2400—2700 Å band in the present compounds as conjugation bands, and of the long-wave bands as those of the unconjugated partial chromophores of benzenoid character. As the groups which constitute the bridges between the phenyl groups in the present compounds are saturated, it is difficult to avoid the conclusion that any conjugation will indeed result in the formation of a diphenyl-type chromophore. Furthermore, notwithstanding the particular features which require interpretation, there is sufficient similarity between the spectra of the present compounds and those of both *o*-substituted and non-*o*-substituted diphenyls generally to provide support for extending both these familiar identifications to the spectra under discussion.

The relationship between the degree of conjugation in diphenyls and the angle between the planes of the phenyl groups is clearly a subject of considerable theoretical importance.* The literature dealing with the qualitative application of quantum-mechanical theory to unsaturated organic molecules is insistent that coplanarity is essential if resonance structures arising from conjugation are to make large contributions to the total structure, but it is difficult to find estimates of the extent to which conjugation occurs if coplanarity is prevented by steric effects. For the compounds examined in this work models suggest that in the oxepins and in the azepinium salts the angles between the ring planes are as large as 50°, thus permitting the introduction of the *oo'*-methoxyl groups without steric interactions occurring. In 9 : 10-dihydrophenanthrene, however, where the angle between the ring planes is *ca.* 20°, the *oo'*-methoxyl groups can only be introduced if some distortion of the molecule occurs. These deductions from models are borne out by the difficulty of bringing about ring closure of the dibromide to give 9 : 10-dihydro-4 : 5-dimethoxyphenanthrene, compared with the ease of formation of 9 : 10-dihydrophenanthrene itself. We should therefore expect the effect of the introduction of methoxyl groups on the spectrum of 9 : 10-dihydrophenanthrene to be different from that on the spectra of oxepin and azepinium compounds.

If hypothesis (*a*) is accepted for compounds (II) and (V), then we may say that the modifications in their spectra resulting from the presence of *oo'*-methoxyl groups are not primarily steric in origin but are due to the interaction of the methoxyl groups with their respective phenyl groups, leading to a decrease in conjugation across the 1 : 1'-bond. Resonance structures such as (IX) and (X) would be expected to reduce the double-bond character of this bond, and this effect would be additional to any steric effect that might

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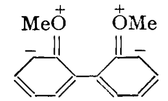
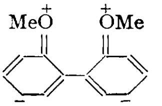
* [*Added in proof*, 18.1.52]. The authors are indebted to Dr. E. A. Braude for drawing their attention to a theoretical paper by Guy (*J. Chim. phys.*, 1949, **46**, 469) on the effects of steric hindrance by *oo'*-dimethyl groups, and of varying the angles between the ring planes, on the degree of conjugation and the ultra-violet absorption spectrum of diphenyl.

operate. In view of the well-known bathochromic and hyperchromic changes which follow the introduction of hydroxyl or alkoxyl into the benzene chromophore (cf. benzene with phenol and anisole; Morton, *op. cit.*), it is suggested that such structures are responsible

(IX)





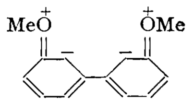
(X)

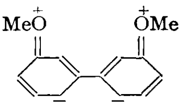
for the decreased conjugation between the phenyl groups, as inferred from the relative intensities of the conjugation bands in (III) and (VIII), when compared with the parent oxepin and azepinium compounds.

In compound (I) distortion of the molecule resulting from the accommodation of the methoxyl groups may take the form of either an increased departure from coplanarity of the phenyl rings or out-of-plane bending of the methoxyl groups themselves. The former can only be achieved at the expense of the resonance energy associated with the conjugation of the phenyl groups and will also be opposed by the energy required to distort the valency angles of the dimethylene bridge (which is probably nearly strain-free for an angle of 20° between the ring planes). If our interpretation of the spectra of compounds (II) and (V) is correct it appears unlikely that such distortion would greatly affect the intensity of the conjugation band. But we should expect the methoxyl groups to exert what we may term their independent substituent effect on the benzene rings, as they do in compounds (III) and (VIII). If, however, the molecular distortion takes the form of bending of the methoxyl groups out of the planes of their respective phenyl rings, then their independent substituent effect on the phenyl rings (with its consequent reduction of the 1 : 1′-bond conjugation) will not operate in full; and the reduction in intensity of the conjugation band will be less than in the dimethoxy-oxepin and -azepinium cation. This, in fact, is what we have observed.

It is clear that the non-steric reduction of conjugation in diphenyls by methoxyl groups should be operative when these are introduced into positions where steric effects are completely absent. Thus, for *mm*′-dimethoxydiphenyl structures such as (XI) and (XII) will reduce the double-bond character of the 1 : 1′-link, and hence favour the unconjugated structure. This has, in fact, already been observed experimentally by Williamson and Rodebush (*loc. cit.*), who determined the absorption spectra of *oo*′-, *mm*′-, and *pp*′-dimethoxydiphenyl. The *oo*′-derivative shows no high-intensity band in the 2500—2700 Å region, but only a band at *ca.* 2800 Å, $\varepsilon_{\text{max.}}$ *ca.* 6000. The *pp*′-derivative gives a conjugation band of increased intensity and at longer wave-length, compared with diphenyl, owing to the favourable orientation of the auxochromic groups; furthermore, there are no long-wave absorption features. The *mm*′-derivative, however, gives a conjugation band of lower intensity than diphenyl, with only a small long-wave shift, and in addition shows a well-resolved band at *ca.* 2900 Å, of about the same intensity as in the *oo*′-compound. Williamson and Rodebush noted that these long-wave bands were similar to the band shown by anisole, and pointed out that in the *mm*′-derivative the methoxyl groups had no steric influence on the possible coplanarity of the molecule. Rather similar differences were noted in comparing the three corresponding dicarboxydiphenyls, though no long-wave absorption features were found in the spectrum of the *mm*′-isomer. It seems likely that many other substituents will be found to reduce the conjugation in diphenyls when introduced into the 3 : 3′-positions; results which have been obtained with various fluoro-derivatives will be given in a subsequent paper in this series.

(XI)

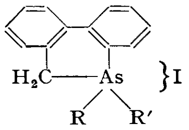




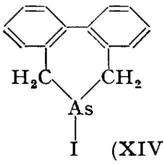
(XII)

The absorption spectra of some arsenic compounds which have been examined by Mann and his co-workers may be briefly considered in the light of the suggestions made above. In compounds of type (XIII; R = Me, R′ = Me or Ph) absorption bands were found

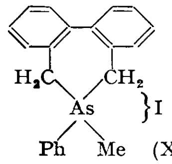
(Cookson and Mann, *J.*, 1949, 2888) at *ca.* 2700 Å, $\varepsilon_{\text{max.}}$ *ca.* 10 000, which were tentatively regarded as conjugation bands. As the angle between the planes of the bridged benzene rings in such compounds was estimated to be *ca.* 34°, the occurrence of a conjugation band of reduced intensity was ascribed to the ability of the benzene groups to oscillate through the coplanar configuration.



(XIII)



(XIV)



(XV)

In compounds (XIV) and (XV) no such bands were observed, the absorption curves rising smoothly with decreasing wave-length in the 2400—3000-Å region and more steeply at shorter wave-lengths to very high values at *ca.* 2300 Å (Beeby, Mann, and Turner, *J.*, 1950, 1923). The absence of conjugation bands in the spectra of these 6-arsa-1 : 2-3 : 4-dibenzo*cyclo*hepta-1 : 3-diene derivatives was explained on the basis of rigid non-coplanar configurations with an estimated angle between the ring planes of *ca.* 63°.

It is sufficient to note here that the appearance of diphenyl-type conjugation bands in the dihydroarsanthridinium salts (XIII) is alternatively explicable on the basis of the suggestion made above that conjugation may still exist in non-coplanar diphenyls with 2 : 2′-bridges, without the necessity for assuming oscillation through the coplanar state of molecules which would be expected to be essentially rigid, as is indeed postulated for compounds of types (XIV) and (XV). The spectra of (XIII; R = Me, R′ = Me or Ph) also show marked inflections at *ca.* 2800 Å, which may be regarded as absorption contributions from the unconjugated benzene partial chromophores. The presence of these long-wave inflections tends to support the identification of the more intense bands at *ca.* 2700 Å as conjugation bands, as the spectra thus contain the complete system of bands to be expected in diphenyls of this type. The spectra of (XIV) and (XV), according to our hypothesis, would also be expected to show conjugation bands. These bands are absent, however, as are long-wave bands from the partial chromophores, which would be expected to be prominent in a completely unconjugated diphenyl.

For these reasons we consider that the spectra of (XIV) and (XV) are determined, not only by the possibility or otherwise of diphenyl-type conjugation, but by some other structural factors, which may be associated with the heterocyclic bridge, and we agree with Cookson and Mann that further investigation of the spectra of heterocyclic arsonium salts would be of interest.

We conclude that the ultra-violet absorption spectrum of a substituted diphenyl must be used with considerable reserve as a criterion of coplanarity or otherwise. The deductions drawn from earlier work in this field, based on comparisons between relatively simple *o*-, *m*-, and *p*-, or *oo*′-, *mm*′-, and *pp*′-substituted compounds, are probably reliable in the main, though some unexplained anomalies have been noted when the substituents were strong auxochromes, as in the case of the dimethoxy- and dicarboxy-diphenyls discussed above. For a particular diphenyl both the *position* and the *nature* of the substituent groups will determine the relative importance of steric and non-steric factors on the strength of conjugation, as indicated by the absorption spectrum.

## EXPERIMENTAL

*Spectroscopic Methods.*—Absorption spectra were measured on a double-beam automatic-recording spectrophotometer designed and built by Holiday and Sutton (to be published). The records obtained are linear in optical density (*D*) against wave-number, as shown in Figs. 1—3, which are direct tracings from the original spectrograms after correction for small instrumental zero errors, obtained by checking the same test solutions at maxima and minima on a Unicam single-beam manual spectrophotometer. All compounds were also examined by the moving-plate, logarithmic-cam method devised by Holiday (*J. Sci. Instr.*, 1937, **14**, 166) in order to locate more accurately any poorly-resolved fine-structure, especially in the weaker long-wave bands. These were more evident in hexane than in ethanol solution; water was used as solvent for the azepinium salts.

2 : 7-*Dihydro*-1-(2-*hydroxy*-1-*methyl*-2-*phenylethyl*)-1-*methyl*-3 : 4-5 : 6-*dibenzazepinium Bromide* (IV).—A solution of (−)-ephedrine hemihydrate (19·2 g., 2·2 mols.) in benzene (200 c.c.) was dried ($Na_2SO_4$). The filtered solution was warmed to *ca.* 50°, and 2 : 2′-bisbromomethyldiphenyl (17 g., 1 mol.) in benzene (90 c.c.) at 50° added to it. The mixture was kept for several hours with intermittent warming; a gum gradually separated. The solution was decanted, and the gum washed several times with benzene and then treated with water. The *bromide* eventually crystallised and was filtered off at 0° and recrystallised from methanol (13·7 g., 60%) (Found: Br, 17·4. $C_{24}H_{26}ONBr,CH_3{\cdot}OH$ requires Br, 17·5%); it had $[\alpha]^{25}_{5461}$ +53·5°, $[\alpha]^{25}_{5791}$ +44·0° (*c*, 1·000 in "AnalaR" chloroform). Fractional crystallisations from methanol produced no change in the specific rotation.

Treatment of a concentrated aqueous solution of the bromide with a saturated solution of potassium iodide gave the sparingly soluble *iodide*, which crystallised in the presence of ethanol in rectangular plates, sometimes coalescing into cubes, and beginning to decompose at 136° (Found: C, 60·3; H, 6·2; I, 24·4. $C_{24}H_{26}ONI,C_2H_5{\cdot}OH$ requires C, 60·35; H, 6·2; I, 24·5%); this had $[\alpha]^{20}_{5461}$ +38·2°, $[\alpha]^{20}_{5791}$ +30·7° (*c*, 1·205 in "AnalaR" chloroform). Fractional crystallisations from ethyl alcohol produced no significant changes in specific rotation.

The iodide later crystallised from acetone in an unsolvated form, having m. p. 226—228° (decomp.) and $[\alpha]^{23}_{5461}$ +41·4°, $[\alpha]^{23}_{5791}$ +33·5° (*c*, 1·2685 in "AnalaR" chloroform) (Found: I, 26·4. $C_{24}H_{26}ONI$ requires I, 26·9%). The specific rotation was unchanged after fractional crystallisation from (*a*) acetone and (*b*) water.

2 : 7-*Dihydro*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1′′′-*piperidinium Bromide* (V).—A chloroform solution of piperidine (8·5 g., 2 mols.) was added gradually to a chloroform solution of 2 : 2′-bisbromomethyldiphenyl (17 g., 1 mol.) (Hall, Lesslie, and Turner, *J.*, 1950, 711); after the brisk reaction was over the mixture was warmed for 5 minutes and then treated with light petroleum (b. p. 40—60°). After decantation of the supernatant liquor the thick oily material formed was dissolved in methanol. Addition of ether precipitated the solid bromide, which was then crystallised from water, the *dihydrate* separating as prisms, m. p. 70—74° (yield, 72%) (Found: Br, 20·9. $C_{19}H_{22}NBr,2H_2O$ requires Br, 21·0%). The anhydrous bromide had m. p. 255°.

2 : 7-*Dihydro*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1′′′-*piperidinium* (+)-*Camphorsulphonate*.—Aqueous ethanolic solutions of the above bromide (37·5 g.) and the equivalent silver (+)-camphorsulphonate were mixed, and the resulting suspension was boiled for ½ hour. Filtration, followed by evaporation to dryness, gave 49 g. of the *spiro*-camphorsulphonate. The product was systematically crystallised from absolute ethanol, but no separation into crops of different specific rotation was observed. Similar crystallisation of 42 g. of the camphorsulphonate from acetonitrile again effected no resolution. Crystallisation from anisole and from chloroform, in which the salt was very soluble, gave similar results. The pure salt had $[\alpha]^{20}_{5791}$ +11·1° ± 0·3°, $[\alpha]^{20}_{5461}$ +14·0° ± 0·3° (*c*, 1·5—5·0 in water) (Found: C, 70·6; H, 7·5. $C_{29}H_{37}O_4NS$ requires C, 70·3; H, 7·5%). The quaternary iodide prepared from the *camphorsulphonate* was inactive.

2 : 7-*Dihydro*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1′′′-*piperidinium* (+)-α-*Bromocamphor*-π-*sulphonate*.—Interaction of the bromide (V) in ethanolic solution with one molecular proportion of silver (+)-α-bromocamphor-π-sulphonate, followed by filtration and evaporation, gave a crystalline *salt*, which was submitted to fractional crystallisation from (*a*) ethanol, (*b*) ethanol–ether, (*c*) benzene–light petroleum, and (*d*) acetonitrile. Over 70 crops were obtained having approximately the same rotation, namely, $[\alpha]^{20}_{5791}$ +50·7° ± 0·5°, $[\alpha]^{20}_{5461}$ +60·4° ± 0·5° (in water), and $[\alpha]^{20}_{5791}$ +56·4° ± 0·5°, $[\alpha]^{20}_{5461}$ +67·2° ± 0·5° (in chloroform) (Found: C, 60·8; H, 6·4. $C_{29}H_{36}O_4NBrS$ requires C, 60·6; H, 6·3%).

4-Phenylpyridine was prepared essentially by the method of Haworth, Hey, and Heilbron (*J.*, 1940, 349). From four experiments in each of which 60 g. of aniline were used, a total of 176 g. of mixed phenylpyridines, b. p. 140—142°/13 mm., was obtained. By successive freezings and crystallisations from light petroleum (b. p. 60—80°) 4-phenylpyridine (28 g.), m. p. *ca.* 60°, was obtained. A boiling alcoholic solution (3400 c.c.) containing picric acid (39·4 g.) and crude 4-phenylpyridine (26·65 g.) gave pure 4-phenylpyridine picrate, m. p. 196°, which was filtered off without the solutions being allowed to cool (the cooling mother-liquor deposited a mixture of 2-, 3-, and 4-isomerides). The original residues from which the 4-phenylpyridine had been obtained by freezing were caused to yield further quantities of 4-phenylpyridine picrate by treating them in boiling ethanolic solution with a quarter of the theoretical amount of picric acid and filtering at the boiling point. A total of 43·5 g. of 4-phenylpyridine picrate was obtained and gave 17·5 g. of pure 4-phenylpyridine.

2 : 7-*Dihydro*-4‴-*phenyl*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium Bromide* (VI).—A benzene solution of 4-phenylpiperidine (19 g., 2 mols.; obtained by reducing 4-phenylpyridine with sodium and ethanol) was added to a benzene solution of 2 : 2′-bisbromomethyldiphenyl (19 g., 1 mol.). The mixture was gently warmed for 10 minutes after the brisk reaction was over. Light petroleum (b. p. 60—80°) was added. An oil separated which became solid on stirring and was crystallised thrice from water. 2 : 7-*Dihydro*-4‴-*phenyl*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium bromide* (15·5 g.) was obtained as stout prisms, m. p. (indef.) >300° (Found : C, 68·6; H, 7·0; Br, 18·45. $C_{25}H_{26}NBr,H_2O$ requires C, 68·5; H, 6·4; Br, 18·2%).

2 : 7-*Dihydro*-4‴-*phenyl*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium* (+)-*camphorsulphonate* was prepared in aqueous solution from 15·5 g. of the bromide (VI). Crystallisation from water, aqueous ethanol, ethanol, or acetonitrile was ineffective in achieving resolution. The salt from ethanol was solvated and had $[\alpha]^{20}_{5791}$ +18·2° ± 0·2°, $[\alpha]^{20}_{5461}$ +21·6° ± 0·2° (*c*, 2·5 in ethanol) (Found : C, 71·0; H, 7·4. $C_{35}H_{41}O_4NS,1\frac{1}{2}C_2H_5\cdot OH$ requires C, 71·2; H, 7·4%).

2 : 7 *Dihydro*-4‴-*phenyl*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium* (+)-α-*bromocamphor*-π-*sulphonate*, prepared in ethanol solution from 13 g. of the above bromide, could not be resolved by crystallisation from ethanol, acetone, or acetonitrile. Crystallisation from acetonitrile sometimes gave voluminous hair-like needles and sometimes stout plates into which the first form passed when kept in contact with solvent; this change occurred in a few seconds when a suspension of the needles was inoculated with the other form. Crystallisation from water also gave no definite indication of resolution although striking differences in crystalline form and solubility were observed. Different *hydrates* were obtained and all had the same specific rotation, $[\alpha]^{20}_{5791}$ +47·8° ± 0·3°, $[\alpha]^{20}_{5461}$ +57·0° ± 0·3° (in chloroform). Different crops were obtained which were either spherical aggregates of needles or sprigs of foliated crystals (Found : C, 61·6; H, 6·2. $C_{35}H_{40}O_4NBrS,2H_2O$ requires C, 61·2; H, 6·4%. Found : C, 63·5; H, 6·4. $C_{35}H_{40}O_4NBrS,\frac{1}{2}H_2O$ requires C, 63·7; H, 6·4%). Recrystallisation of the above hydrates gave *salts* having $\frac{1}{2}H_2O$ and $1\frac{1}{2}H_2O$ respectively (Found : C, 62·4; H, 6·4. $C_{35}H_{40}O_4NBrS,1\frac{1}{2}H_2O$ requires C, 62·0; H, 6·4%). Over 60 crops of (+)-bromocamphorsulphonate were examined. The quaternary picrate prepared from the bromocamphorsulphonate was inactive.

1 : 1-*Diethyl*-2 : 7-*dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium Iodide* (VII).—2 : 2′-Bisbromomethyl-6 : 6′-dimethoxydiphenyl (Hall and Turner, *loc. cit.*) (70 g., 1 mol.) was dissolved in warm benzene (30 c.c.), and diethylamine (2·8 g., 2·2 mols.) added. The quaternary bromide separated almost immediately, and precipitation was completed by addition of light petroleum. The bromide was filtered off, dissolved in water, in which it was very soluble, and reprecipitated as the iodide by the addition of hot aqueous potassium iodide. 1 : 1-*Diethyl*-2 : 7-*dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium iodide* (5·9 g., 77%) crystallised from water in rectangular plates (Found : I, 28·7. $C_{20}H_{26}O_2NI$ requires I, 28·9%).

1 : 1-*Diethyl*-2 : 7-*dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium* (+)-*camphorsulphonate* was prepared in aqueous solution. Evaporation of the filtered solution gave a syrup which eventually crystallised in the presence of ethyl acetate. The salt (4·3 g.) was first recrystallised from acetone but could not again be obtained crystalline from this solvent. It was then crystallised from a mixture of ethyl propionate and ethyl acetate, the salt obtained almost certainly containing ethyl acetate of crystallisation; this was readily lost during short drying *in vacuo* and after such treatment the salt had m. p. 218°, $[\alpha]^{21}_{5461}$+ 22·3°, $[\alpha]^{21}_{5791}$ +19·2° (*c*, 0·9635 in ethanol) (Found : C, 66·0; H, 7·4. $C_{30}H_{41}O_6NS$ requires C, 66·3; H, 7·6%). There was no indication of separation of diastereoisomerides from this solvent and the various crops were therefore combined and crystallised by dissolving them in benzene containing a little methanol and boiling off the methanol to the point of turbidity. The salt again appeared to be solvated but the solvent was readily lost *in vacuo* and the unsolvated salt had m. p. 218°, $[\alpha]^{21}_{5461}$ +22·5°, $[\alpha]^{21}_{5791}$ +19·8° (*c*, 1·0875 in ethanol) (Found : C, 65·8; H, 7·4%). There was no change in specific rotation on further fractional crystallisation, and as the salt frequently separated first as a gum it was finally abandoned.

2 : 7-*Dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium Bromide* (VIII).—2 : 2′-Bisbromomethyl-6 : 6′-dimethoxydiphenyl (21 g., 1 mol.) was dissolved in warm benzene (120 c.c.), and piperidine (9·8 g., 2·2 mols.) added. After 1 hour the benzene was decanted, and the residual gum washed with light petroleum. On the addition of a little water the gum crystallised and was filtered off at 0°. The *bromide dihydrate* (19 g., 82%), recrystallised

from water (with ice-cooling), had m. p. 114° (rhombic plates) (Found: Br, 17·8. $C_{21}H_{26}O_2NBr,2H_2O$ requires Br, 18·15%). It tended to effloresce on air-drying.

(—)-2 : 7-*Dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 :6-*dibenzazepinium*-1-spiro-1‴-*piperidinium* (+)-*Camphorsulphonate.*—The above bromide was treated with silver (+)-camphorsulphonate in aqueous solution, and the filtered solution evaporated to dryness. The residue was crystallised from acetone, and the salt obtained (25 g.) subjected to repeated fractional crystallisations from small volumes of acetonitrile. In this way 1·25 g. of the less soluble (—)-2 : 7-*dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium* (+)-*camphorsulphonate* were obtained and had m. p. 248—250°, $[\alpha]_{5461}^{21}$ +19·0°, $[\alpha]_{5791}^{21}$ +15·8° (*c*, 1·105 in ethanol) (Found: C, 67·5; H, 7·3. $C_{31}H_{41}O_6NS$ requires C, 67·0; H, 7·4%).

(—)-*Dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium Iodide.*—Treatment of an aqueous solution of the above camphorsulphonate with saturated potassium iodide solution gave a precipitate of (—)-2 : 7-*dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium iodide*; crystallised from ethanol, this had $[\alpha]_{5461}^{22}$ −3·8° ± 0·2°, $[\alpha]_{5791}^{22}$ −3·4° ± 0·2° (*c*, 2·3485 in acetonitrile) (Found: C, 56·3; H, 5·9; I, 28·5. $C_{21}H_{26}O_2NI$ requires C, 55·9; H, 5·8; I, 28·1%).

(+)-2 : 7-*Dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium* (—)-*Camphorsulphonate.*—The more soluble (+)-camphorsulphonate was obtained with $[\alpha]_{5461}^{20}$ +24·7°, $[\alpha]_{5791}^{20}$ +20·8° (*c*, 1·1 in ethanol), and gave an iodide with $[\alpha]_{5461}^{18}$ + 1·3° (*c*, 3·58 in acetonitrile) but was too soluble in acetonitrile to be further purified. Accordingly all the (+)-camphorsulphonate with $[\alpha]_{5461} > +23·5°$ was converted into the iodide and thence into the (—)-camphorsulphonate. The silver (—)-camphorsulphonate used had a slightly lower specific rotation than the silver (+)-camphorsulphonate ($[\alpha]_{5461}^{19}$ −18·3°, $[\alpha]_{5461}^{19}$ +19·7°, both 1% solutions in water) and recrystallisation of the salt made from it gave 0·7 g. of (+)-2 : 7-*dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium* (—)-*camphorsulphonate* with m. p. 245—248°, $[\alpha]_{5461}^{18}$ −14·5°, $[\alpha]_{5791}^{18}$ −12·0° (*c*, 1·063 in ethanol) (Found: C, 67·4; H, 7·3. $C_{31}H_{41}O_6NS$ requires C, 67·0; H, 7·4%).

(+)-2 : 7-*Dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium Iodide.*—Treatment of an aqueous solution of the above (—)-camphorsulphonate with saturated potassium iodide solution gave a precipitate of (+)-2 : 7-*dihydro*-4′ : 1″-*dimethoxy*-3 : 4-5 : 6-*dibenzazepinium*-1-spiro-1‴-*piperidinium iodide*. It was crystallised from ethanol and had $[\alpha]_{5461}^{22}$ +4·0° ± 0·4°, $[\alpha]_{5791}^{22}$ +3·6° ± 0·4° (*c*, 1·1135 in acetonitrile) (Found: C, 55·6; H, 5·9. $C_{21}H_{26}O_2NI$ requires C, 55·9; H, 5·8%).

During this resolution no fewer than 84 crops of camphorsulphonates were examined polarimetrically.

*Dimorphism of the* (+)- *and* (—)-*Iodides.*—The m. p.s of the active iodides (as taken by the capillary-tube method) were not sharp and underwent large changes on recrystallisation both from ethanol and from water. The m. p.s were then taken under a microscope on a Kofler heating stage and two distinct crystalline forms were recognisable. One form consisted of hexagonal plates, m. p. 215—218°, and the other of irregular prisms which macroscopically appeared sometimes as plates and sometimes as rods, and had m. p. 242—245°. Frequently, crystallisation gave mixtures of the two forms, which were readily distinguishable under the microscope and melted separately at the respective temperatures given above.

*Racemisation of the* (—)-*Iodide.*—The iodide with $[\alpha]_{5461}^{22}$ −2·9° was boiled under reflux in *cyclo*hexanol (b. p. 160°) solution for 8 hours and then precipitated with ether. The specific rotation was then $[\alpha]_{5461}^{19}$ −0·6°; after being boiled for a further 8 hours in *cyclo*hexanol the recovered iodide was inactive.

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